A MONTHLY SCIENTIFIC PUBLICATION OF THE AMERICAN HEART ASSOCIATION, INC.

MODERN CONCEPTS OF CARDIOVASCULAR DISEASE

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Editorial Office: JOHNS HOPKINS HOSPITAL, BALTIMORE 5, MARYLAND

Vol. XXX APRIL 1961 No. 4

Auscultation of the Heart: Part II*

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MURMURS

Murmurs are audible vibrations produced by the flow of blood. These vibrations originate in either the heart or great vessels as a result of turbulent blood flow, which produces a noise recognized as a murmur. The turbulence is due to hemodynamic changes in the cardiovascular system.

Blood flow through normal vascular channels is described as laminar, or streamlined, flow and is silent. Turbulent flow, which is noisy, may develop in the cardiovascular system under certain special circumstances. The factors determining whether flow will be laminar or turbulent are the radius of the channel, and the velocity, density, and viscosity of the fluid medium. The viscosity and density of blood are reasonably constant, but the velocity of flow and the radii of the parts of the cardiovascular system vary considerably and abruptly in both normal and pathological conditions. It is probable that some turbulence normally exists at specific points, such as in the aorta or pulmonary artery just beyond the valves, but the noise produced is not intense enough to be heard with the stethoscope. A systolic murmur can, however, frequently be recorded from the pulmonary artery by means of a microphone placed at the tip of a cardiac catheter.

Such minimal turbulence can be increased and result in an audible murmur when the velocity of blood flow is increased, as it is in fever, exercise, pregnancy, or hyperthyroidism. On the other hand, when the normal variation in caliber within the cardiovascular system is exaggerated by disease, a murmur may result at normal or decreased flow. For example, blood flowing through a normal aortic valve into a dilated aorta or through a stenotic valve into a normal aorta causes a murmur.

Another mechanism by which murmurs may be produced is vibration of a structure within the heart, such as a ruptured valve cusp or chorda tendinea. This usually produces a murmur which is musical in quality, since the process is similar to the vibration of a violin string.

CLASSIFICATION

The classification of murmurs is generally unsatisfactory. In any classification, however, the following factors must be taken into account: timing, duration, intensity, pitch, quality, constancy, and location.

Timing

Murmurs must be placed in either systole or diastole, except for those which are continuous or occur during parts of both phases of the cardiac cycle. This is accomplished by relating the murmur to the first and second heart sounds. Systolic murmurs follow the first heart sound and precede the second heart sound, while the reverse is true of diastolic murmurs. At times, one or the other sound is obscured by the murmur, but it is rare for both sounds to be inaudible in all areas. In such cases, the apical impulse or the carotid pulsation can be used to identify the systolic phase. It is customary to classify systolic murmurs further as early, middle, or late systolic depending on the

* Part I of this article appeared in the March, 1961, issue.

phase of systole, and diastolic murmurs as early and middle diastolic and presystolic (late diastolic) depending on the phase of diastole in which they occur.

Duration

Murmurs are usually classified as short, intermediate, or long, and those which occupy an entire phase of the cardiac cycle are called holosystolic or holodiastolic.

Intensity

There are many systems which attempt to grade the loudness of murmurs, either in words or in numbers. Levine grades them from a barely audible murmur (grade I) to one which can be heard with the stethoscope lifted off the chest wall (grade VI). Others identify the same spectrum of sound using only four numbers, and still others prefer the words "faint," "moderately loud," "loud," etc., to express the same variations in intensity. Such classification is never precise because of the subjective nature of the process, individual variations among observers, and differences in the conditions under which the observations are made.

Pitch

In general, heart sounds and murmurs are considered low pitched if they fall in the range of 30 to 80 c.p.s., medium pitched from 80 to 120 c.p.s., and high pitched above 120 c.p.s. Pitch and intensity usually define the quality of a murmur. The blowing decrescendo diastolic murmur of aortic or pulmonic insufficiency is usually high pitched, while the rumbling diastolic murmur of mitral stenosis is relatively low pitched.

Quality

Murmurs are generally classified as blowing, harsh, musical, or rumbling. These qualities are closely related to the pitch and intensity of the fundamental tone as well as the harmonics, if any are audible. If the frequency is relatively constant, the murmur will have a musical quality. The importance of recognizing the quality of murmurs lies in the fact that specific valvular lesions can be recognized by the quality and timing of the murmurs, even when heard in an atypical area.

Constancy

Constancy is important in evaluating systolic murmurs which may or may not be of pathological significance. Most pathological murmurs are constant. Exceptions to this rule occur in severe heart failure with low cardiac output when pathological murmurs may become barely audible, and in bacterial endocarditis when there may be a gradual change in existing murmurs. Diastolic murmurs are of pathological significance whether or not they are constant.

Location

It is unwise to place too much importance on the location of a murmur, but certain lesions are associated with murmurs in specific locations. The "diamond-shaped" murmur of aortic stenosis is usually heard best at the second right intercostal space and radiates into the neck. It may also be heard well at the apex, and at times even better than in the classical area. In such cases, the quality and timing of the murmur distinguish it from the murmur of mitral insufficiency. The blowing diastolic murmur of aortic insufficiency is heard in the second right intercostal space and along the left sternal border. The murmur of pulmonic insufficiency is heard in the latter location, and cannot be differentiated by auscultation from that of aortic insufficiency. The murmur of pulmonic stenosis, which also displays midsystolic accentuation, is heard best to the left of the sternum in the second intercostal space. The murmur of mitral insufficiency is heard best at the cardiac apex and axilla, while the similar murmur of tricuspid insufficiency is usually heard better further to the right or over the xiphoid. The same is true for the diastolic murmurs of mitral and tricuspid stenosis. The murmurs of certain congenital lesions are also sought in classical areas, but they may be quite variable, and criteria other than location are used to identify them.

THRILLS

A thrill is a palpable manifestation of the loudness (intensity) of a murmur and has no additional significance in itself.

SYSTOLIC MURMURS

Systolic murmurs are those which originate with or after the first heart sound, and end with or before the second heart sound. Leatham[1] has classified them into ejection and regurgitant murmurs. The ejection murmur is one with midsystolic accentuation, such as that heard in aortic and pulmonic stenosis. A regurgitant systolic murmur is holosystolic, beginning immediately after the first sound and extending

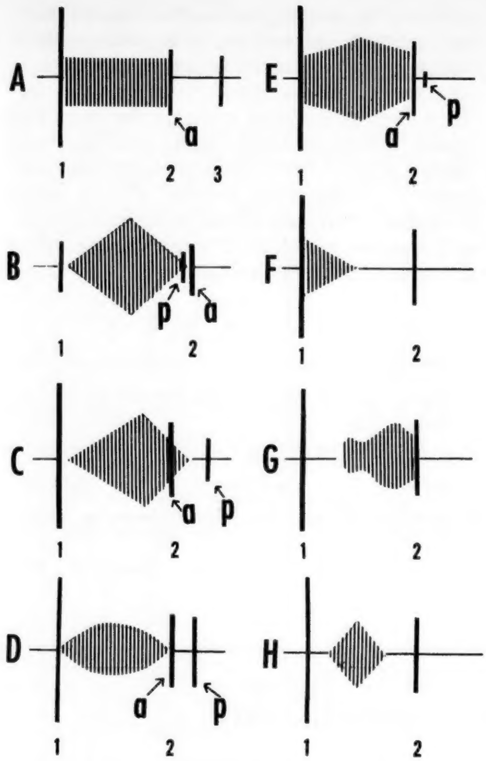

Figure 3. *(A) Typical systolic murmur of mitral insufficiency at the cardiac apex. Note that the murmur begins immediately after the first sound and extends to or slightly beyond the aortic component (a) of the second sound, which may be overshadowed by the murmur and difficult to identify. A loud third heart sound, frequently mistaken for a second sound, is usually present. (B) Typical "diamond-shaped" murmur of aortic stenosis in the aortic area. Both the first and second sounds are diminished in intensity, and left ventricular systole is often prolonged, making the aortic component late and burying the pulmonic component (p) in the murmur. (C) Similar murmur of pulmonic stenosis with intact ventricular septum, as heard in the pulmonic area. In this case, right ventricular systole is prolonged and the pulmonic component is delayed, being heard well beyond the end of the murmur. (D) Murmur of atrial septal defect heard over the pulmonic area. The systolic murmur may be quite variable, and diastolic flow murmurs may be present at times. The important finding is the rather marked fixed splitting of the second sound, with the pulmonic component being considerably later than the aortic component. (E) The murmur of ventricular septal defect at the left sternal border. This is a loud, harsh, holosystolic murmur which is somewhat variable but may have a crescendo-decrescendo character. The second sound is frequently split. (F, G, and H) Three types of murmurs heard at the cardiac apex during systole. (F) begins immediately after the first sound, but lasts only part way through systole; it is usually nonpathological, but can represent very mild mitral insufficiency. (G) begins near midsystole and lasts until the second sound; in our experience, it is nonpathological. (H) is a midsystolic murmur of short duration, which also is nonpathological. These murmurs, common in children, are often loud and high pitched.*

throughout systole, with fairly constant intensity.

To differentiate pathological from nonpathological systolic murmurs is a difficult problem, which often cannot be resolved on a single examination. Pathological murmurs, in general, are persistent, of moderate to long duration, and start with or shortly after the first sound. Except in children, loud murmurs are more likely to be pathological than soft ones. Murmurs which begin in middle to late systole, or which start with the first sound but are of short duration, are generally not pathological in origin (fig. 3 F, G, and H). These murmurs are produced by increased velocity of blood flow, cardiorespiratory factors, and other mechanisms which are not known.

The words "innocent" and "functional" are other terms used to identify nonpathological murmurs. Frequently, a murmur cannot be evaluated properly unless related to history, to other physical evidence of heart disease such as increased size on x-ray, or to electrocardiographic or other laboratory evidence of cardiac abnormality.

Specific Systolic Murmurs

The murmurs of mitral and tricuspid regurgitation, whether the valve is insufficient and diseased or incompetent because of a dilated annulus, are similar in quality because the mechanism is the same. When the pressure in the ventricle exceeds that in the corresponding atrium, the mitral and tricuspid valves close, resulting in the first heart sound. If closure is not complete, blood is forced into the atrium under pressure, causing turbulence and, hence, a murmur. Usually, the murmur (fig. 3A) begins immediately after the first sound and extends throughout systole, ending with the second sound, although in *mild* mitral insufficiency the murmur may end before the aortic component of the second sound.

The murmurs of aortic stenosis (fig. 3B), both congenital and acquired, and of pulmonic stenosis (fig. 3C), which is usually congenital, have a so-called "diamond" shape when visualized on a phonocardiogram. Since the intensity of the murmur is related to ejection of blood,

the murmur is loudest when the ejection is at its maximum, that is, in midsystole. When stenosis is severe, the ejection of blood is delayed and maximum accentuation occurs later in systole.

With dilatation of the ascending aorta or pulmonary artery, there is no real obstruction to the passage of blood, so the maximum accentuation of the systolic murmur, which may accompany this condition, usually occurs early in systole.

With atrial septal defects of the secundum type and with anomalous pulmonary venous drainage, a systolic murmur (fig. 3D) is frequently present in the pulmonic area, due to the large flow of blood past the pulmonic valve into an artery which is often dilated. The murmur so produced usually has an early systolic accentuation, although at times it may sound very much like the murmur of pulmonic stenosis.

With ventricular septal defects (fig. 3E), on the other hand, the murmur is related to the passage of blood through a small defect which acts much like a stenotic valve. The resulting murmur, best heard in the third and fourth left interspaces at the sternal border, is loud and harsh and often has a midsystolic accentuation.

The murmur of coarctation of the aorta is also produced by the flow of blood through a constriction, but, since the narrowing is some distance from the heart, the murmur begins some time after the first sound, and often extends past the second sound into early diastole. There is often a "diamond-shaped" configuration, although the intensity of the murmur is quite variable. It is often louder in the back than in the aortic area. Dilated intercostal vessels, due to collateral circulation, also contribute to the murmur.

DIASTOLIC MURMURS

At the end of systole, ventricular pressure falls below atrial pressure, and the mitral and tricuspid valves open (fig. 4). There is a period of rapid blood flow into the relaxing ventricles, followed by a period of minimal flow during midsystole. In the presystolic period, with normal sinus rhythm, atrial contraction forces more blood into the ventricles. When the mitral or tricuspid valve becomes stenotic, the flow of blood is impeded and murmurs (fig. 5A) result during the periods of maximal flow, that is, early diastole and presystole. When stenosis is severe, left atrial pressure remains elevated throughout diastole and the murmur is holodiastolic, although there is still an accentuation during the presystolic phase, due to atrial contraction. When there is atrial fibrillation, the characteristic murmur of mitral stenosis does not disappear, but loses its presystolic accentuation. The low-pitched, rumbling quality of this murmur is probably related to the low pressure gradient across the valve.

The opening snap of the mitral valve, when present, is one of the early signs of mitral stenosis, and in early cases it is widely separated from the components of the second sound. As the left atrial pressure becomes elevated, the opening of the mitral valve occurs earlier in diastole, and the opening snap moves closer to the second sound (fig. 4). In these cases, it may be confused with splitting of the second sound, but the accentuation of the pulmonic

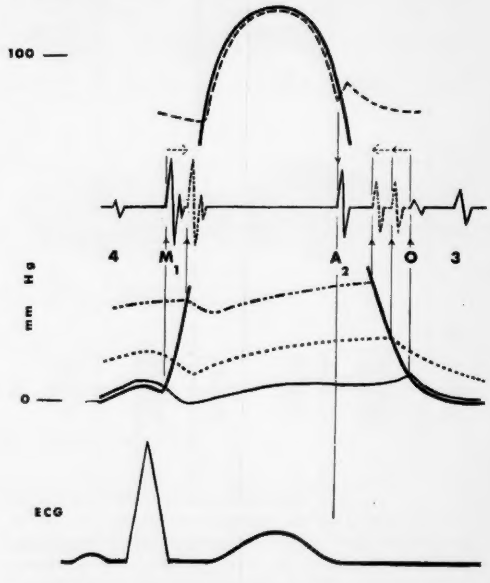

Figure 4. *The upper portion of this figure shows left ventricular and aortic pressure curves. The dotted lines in the lower portion represent two different elevated left atrial pressure curves resulting from mitral stenosis. The normal left atrial pressure is indicated by the solid line below these dotted lines. (M_1) = mitral component of the first heart sound; (A_2) = aortic component of the second heart sound; (O) = opening time of the normal mitral valve. Mitral-valve opening is not heard if the valve is normal, but becomes audible with disease resulting in mitral stenosis. The sound resulting at the two elevated levels of left atrial pressure are shown in dotted lines between A_2 and O. (3) and (4) refer to the third and fourth heart sounds. (Revised from figure reprinted by permission of Grune & Stratton, Inc., from Butterworth, J. S., et al.: Cardiac Auscultation, ed. 2, New York, Grune & Stratton, 1960.)*

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component, usually existing in the more severe cases, makes differentiation rather easy. In mild cases, with wider separation, the opening snap may be confused with the third heart sound, but its sharp, snapping quality is usually easily differentiated from the dull, thudding quality of the third heart sound. In very severe stenosis with rapid heart rate, the opening snap may merge with the components of the second heart sound, and in extremely advanced cases, usually with heavy calcification, it may be absent.

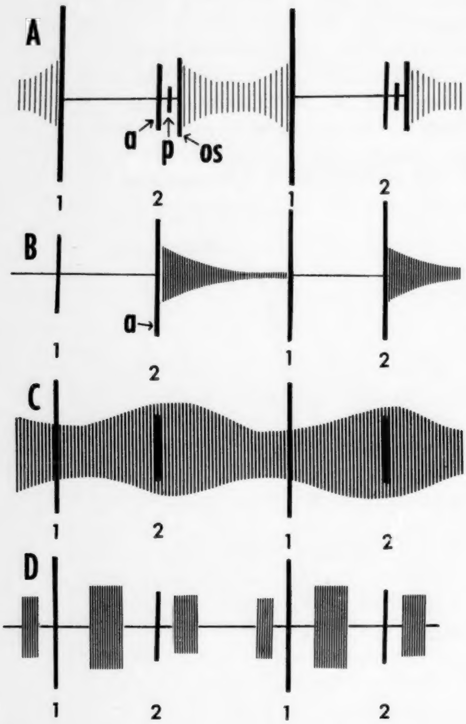

Figure 5. *(A) Typical murmur of mitral stenosis at the cardiac apex: (a) is the aortic component of the second sound and (p) the pulmonic component; (os) represents the opening snap of the mitral valve, which is followed immediately by a low-pitched holodiastolic murmur with accentuation in early diastole and presystole. (B) Decrescendo diastolic murmur of aortic insufficiency at the left sternal border. This is a relatively high-pitched murmur starting immediately after the aortic component of the second sound, which is often increased in intensity. (C) Typical continuous "machinery-like" murmur of patent ductus arteriosus, as heard in the pulmonic area. The murmur is usually accentuated in late systole; the second sound may be buried in the murmur, and, at times, the first heart sound may be difficult to identify. (D) This is a representation of the short, higher-pitched sounds frequently encountered in pericardial rubs. These sounds are shown as occurring in presystole, systole, and early diastole. Rubs may be extremely variable, and all components shown are not always present.*

Insufficiency of the aortic valve, due to valvular disease or to dilatation of the valvular ring, produces a blowing decrescendo diastolic murmur (fig. 5B) which begins immediately after the second sound. Since the pressure gradient is greatest in early diastole, the murmur is heard best at that time and diminishes in intensity as the gradient decreases. The murmur is often quite faint. At times, it can be heard best during deep expiration, with the patient leaning forward slightly, but these conditions are not always helpful.

The murmur of pulmonic insufficiency or incompetence has the same quality and is heard in the same location as that of aortic insufficiency. This murmur is named after Dr. Graham Steell, who described it in 1888. It is indistinguishable by auscultation from the much more common murmur of aortic insufficiency. However, the murmur of pulmonic incompetence is found in conditions with pulmonary hypertension, and there is usually a marked accentuation of the pulmonary component of the second sound to aid in differentiating it from the murmur of aortic insufficiency.

CONTINUOUS MURMURS AND SOUNDS

The classical murmur of patent ductus arteriosus (fig. 5C) is a continuous "machinery-like" murmur, heard best in the pulmonic or left infraclavicular area. It is the result of blood flowing from the aorta into the pulmonary artery during both phases of the cardiac cycle. Since the pressure gradient between the two vessels is greater in systole, the intensity of the murmur is greatest during that phase. Maximum accentuation usually occurs late in systole and often obscures the second sound. The late accentuation is probably due to the distance of the ductus from the heart. When pulmonary pressure is elevated, the diastolic component may disappear, leaving only a systolic murmur. The pulmonic component of the second sound is usually accentuated in such cases.

Arteriovenous fistulae produce continuous murmurs by the same mechanism as described above. Indeed, patent ductus arteriosus is one variety of arteriovenous fistula. The murmur will be accentuated at the time of maximum velocity of flow through the communication, and thus the accentuation will be delayed, with the length of delay depending on the distance

from the heart. Peripheral fistulae can sometimes be compressed, and the murmur is then obliterated.

The venous hum is a continuous sound, heard in the neck or upper thorax, which may be confused with the murmur of patent ductus arteriosus. It is due to rapid blood flow through the venous system. The hum is heard best in the upright position and often disappears in the supine position. Finger compression of the jugular veins or turning the head usually abolishes the murmur.

Pericardial rubs (fig. 5D) are rough grating sounds heard during systole and diastole, either as a continuous sound or during limited portions of each phase. They may be faint or loud, but have a tendency to sound close to the ear. They are usually of higher pitch than most murmurs and are much more variable.

SUMMARY

An attempt has been made to discuss briefly some of the physical and hemodynamic principles which govern production of heart sounds and murmurs, as well as some factors which influence their recognition under clinical circumstances. Since limited space prevents detailed discussion of this material, the interested reader is referred to the many excellent textbooks on the subject, some of which are listed below.[2-6] These texts provide a more comprehensive treatment of the points brought out in this paper, as well as extensive bibliographies of current and historical literature.

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